ACCELERATOR FOR ION IMPLANTATION

TECHNICAL FIELD

The present invention relates to Ion Implantation generally, and more specifically concerns a radio frequency ion accelerator.

BACKGROUND ART

Use of ion beams for treating workpieces is known in the prior art. Charged ions are accelerated to a velocity and focused to impinge upon a workpiece. This procedure can be used to harden materials and has been utilized for doping semi-conductor substrates. In one semi-conductor application, a focused beam of ions is directed along a controlled path to impinge upon semi-conductor wafers. The wafers are mounted to a support that can be rotated and translated. Controlled combinations of these movements cause a specific concentration of ion doping of the semi-conductor wafers.

Two prior art patents assigned to the assignee of the present invention disclose apparatus for use in ion implantation of semi-conductor materials. A first patent to Ryding (U.S. Pat. No. 4,234,797) entitled "Treating Workpieces With Beams" discloses a control mechanism for achieving uniform ion doping of semi-conductor substrates. The Ryding apparatus includes a beam neutralizer to control charge build up on the semi-conductor wafers. A second patent to Benveniste (U.S. Pat. No. 4,419,584) entitled "Treating Workpiece With Beams" discloses apparatus for controlling the temperature of a workpiece treating system specifically used for semi-conductor ion doping. The subject matter of these two prior art patents as specifically incorporated herein by reference.

Ion beams used with these treatment systems are accelerated with a static electric field generated by a direct current potential applied to an accelerating electrode. As is known, a charged particle (ion) experiencing a uniform electric field is accelerated by a force proportional to the charge on the particle times the field strength that particle experiences. The final velocity achievable through static field acceleration of a particle can be increased by either increasing the path through which the particle accelerates or increasing the field strength the particle experiences.

To achieve the ion energies necessary for beam implantation, the accelerating potential must be many thousands of volts. Energies up to 2 million electron volts are desirable for deep ion implantation of semi-conductor material. At these extremely high voltages, use of a direct current accelerating potential becomes difficult and complicated. At any voltage above 100 kilovolts, high direct current voltages must be electrically isolated from other components of the beam treatment system such as the ion source, gas handling and vacuum systems, control electronics, and beam analyzing magnet.

These prior art devices are also limited since the accelerated beam is at different dc voltage than the injected beam, the difference being the accelerating voltage. Alternately, the accelerated beam is at the same dc voltage as the injected beam but the charge state is changed in sign (and possibly magnitude) during acceleration which greatly limits the beam current.

Beam treatment apparatus must be flexible if it is to be used to accelerate different atomic number ions. It is desirable, for example, that the same accelerating, focusing, and analyzing equipment be suitable for different ions. This equipment should have pratical simplicity and modest dimensions and be produced at a reasonable cost if the ion implantation system is to have commercial viability.

DISCLOSURE OF THE INVENTION

The present particle accelerator produces particle accelerating electric fields which vary periodically with time. The phase of these fields is adjustable to accommodate different atomic number particles as well as particles having different initial conditions, i.e. speeds with which they enter the particle accelerator. This is accomplished in a straightforward way, compared with the technical difficulties needed to accelerate particles using static d.c. fields, yet produces high energies suitable for deep ion implantation.

The ion implantation apparatus of the invention includes a source to produce a beam of charged ions moving at an initial velocity. A radio frequency accelerator has a sequence of electrodes that create an alternating electric field to further accelerate the ions. Each electrode is electrically coupled to an energizing circuit which applies alternating current potential having a specified frequency, amplitude, and phase to accelerate the ions entering the accelerator. After the ions are accelerated, a pulsed beam of those ions can be directed to a workpiece.

This invention is of major importance in ion implantation of semiconductors and other material. The radio frequency accelerator can accelerate heavy atomic particles possessing a low charge to mass ratio from an energy of as low as 80 keV per electronic charge state to energies up to and exceeding 1 meV per electronic charge state. A single configuration of the invention is capable of achieving variable energy acceleration for a broad range of different particle species, with a charge to mass ratio (q/A) that can spread over more than a decade range (10 to 1). For example, a single configuration can accelerate any of the following typical ions used in semiconductor implantation:

Boron	B^{2+} (q/A = 1/5), B^{+}
Phosphorous	p^{2+}, p^{+}
Arsenic	As^{2+}, As^{+}
Antimony	Sb^{2+} (q/A = 1/60)

Unlike prior art accelerators, the invention offers at once all four of the following features:

(a) low injection energy compared with the final energy after acceleration,

(b) low charge to mass ratios, for example down to q/A=1/130, and

(c) a broad range of charge to mass ratios, for example q/A=1/10 to 1/130 or q/A−1/5 to 1/60.